

REMARKS

Claims 1 to 16, as amended, appear in this application for the Examiner's review and consideration. The amendments are fully supported by the specification and claims as originally filed. Therefore, there is no issue of new matter.

Claims 1 to 15 stand rejected under 35 U.S.C. § 103(a), as allegedly being unpatentable over U.S. Patent No. 5,788,945 to Schei in view of U.S. Patent No. 6,368,403 to Schmid et al (Schmid) and further in view of International Publication No. WO 89/02415 to Mellström et al. (Mellström), for the reasons set forth on pages 2 to 6 of the Office Action; and

Claim 16 stands rejected under 35 U.S.C. § 103(a), as allegedly being unpatentable over Schei in view of Schmid and Mellström and further in view of Hurley, for the reasons set forth on page 7 of the Office Action.

In response, Applicants submit that the presently claimed invention is directed to a method for removing boron from silicon. The claimed method comprises heating metal silicon, containing boron as an impurity, to a temperature ranging from the melting point of silicon to 2200°C to place it in a molten state. A solid mainly comprising silicon dioxide and a solid mainly comprising one or both of a carbonate of an alkali metal or a hydrate of a carbonate of an alkali metal is then added into the molten silicon, forming a slag on the molten silicon, removing the boron from the silicon.

In contrast to the presently claimed method, Schei discloses a process for removing impurities from molten silicon by treatment of molten silicon in a vessel with a slag having the capacity of removing the impurities particularly boron from molten silicon. In particular, as cited in the Office Action, Schei discloses the continuous or substantially continuous addition of slag, having a lower density than molten silicon, to molten silicon through the bottom or the lower part of a vessel containing molten silicon, such that the slag rises to the top of the molten silicon, and the slag is continuously or substantially continuously removed from the vessel. *See* Schei, column 3, lines 27-33. Schei further discloses that the slag based on $\text{Na}_2\text{O} \cdot \text{SiO}_2$ is an example of slag having a lower density than silicon *See* Schei, column 3, lines 33 to 35.

Although Schei discloses the addition of a $\text{Na}_2\text{O} \cdot \text{SiO}_2$ slag to molten silicon, Schei fails to disclose or suggest anything regarding the addition of Na_2CO_3 or any other carbonate of an alkali metal or of a hydrate of a carbonate of an alkali metal to molten silicon, as presently claimed. As discussed above, the presently claimed method requires the addition of

a solid mainly comprising silicon dioxide and a solid mainly comprising one or both of a carbonate of an alkali metal or a hydrate of a carbonate of an alkali metal to the molten silicon, forming a slag on the said molten silicon. Na_2O is not a carbonate of an alkali metal or a hydrate of a carbonate of an alkali metal, and has significantly different chemical properties than an alkali metal carbonate. In particular, as will be understood by those skilled in the art, alkali metal carbonates decompose at high temperatures, such as the melting temperature of silicon. In the decomposition, the carbonate releases carbon dioxide, CO_2 , gas.

In addition, Schei fails to disclose or suggest supplying the constituents of the slag to the molten silicon in powder form, as presently claimed. Accordingly, Schei fails to provide any reason for one of ordinary skill in the art to make or use the presently claimed method.

Schmid does nothing to overcome the deficiencies of Schei. Schmid is cited in the Office Action for the disclosure of a method for purifying silicon in which silica powder is introduced as a reactant for molten silicon to form a slag containing the silica powder and impurities in the molten silicon. The Office Action further states that Schmid discloses the addition of certain powders, such as CaO powder, to make the slag more basic, and, thus, allow it to trap impurities.

According to the Office Action, it would allegedly have been obvious to one of ordinary skill in the art at the time of the invention to substitute the powder form of $\text{CaO}\cdot\text{SiO}_2$ taught by Schmid for the $\text{Na}_2\text{O}\cdot\text{SiO}_2$ slag added by Schei to the molten silicon, as silica powder and calcium oxide powder are generally known for use in slag, and introducing silica and CaO in powder form eliminates the step of heating these components separately to form slag before introduction to the molten silicon.

However, as will be recognized by those skilled in the art, CaO is not a carbonate of an alkali metal or a hydrate of a carbonate of an alkali metal used in the presently claimed method. CaO is an oxide of an alkaline earth metal. Clearly, the substitution of CaO for the CaO in the $\text{Na}_2\text{O}\cdot\text{SiO}_2$ slag disclosed by Schei would not provide the presently claimed method.

In addition, as recited in claim 1, Schmid disclose a method and apparatus for purifying silicon. The disclosed method comprises heating molten silicon in a container, and providing controllable amounts of oxygen gas and hydrogen gas to the molten silicon. The molten silicon is purified by stirring, slag reaction with moisture, oxidation, evacuation, and reduction by introducing oxygen and hydrogen gas in separately controllable amounts. The

hydrogen and oxygen are added by an oxygen-hydrogen torch or lance that has a flame surrounded by an inert gas, such as argon.

Schmid also discloses that SiO_2 powder can be introduced as a reactant for molten silicon to form a slag, and also discloses addition of CaO , as stated in the Office Action, and/or CaF_2 powder to make the slag more basic. The SiO_2 powder is added to the silicon in the inert gas of the torch or lance. *See* Schmid, column 2, lines 3 to 20, and column 5, lines 1 to 11.

Although Schmid discloses addition of SiO_2 powder and the further addition of CaO and/or CaF_2 powder to the molten silicon, Schmid requires the introduction of oxygen and hydrogen gas into the molten silicon as well. That is, even if the SiO_2 powder and CaO and/or CaF_2 powder are added to the molten silicon, the disclosed method does not purify the molten silicon without the introduction of oxygen and hydrogen gas from a torch within the molten silicon. Schmid does not suggest addition of SiO_2 powder and the further addition of CaO and/or CaF_2 powder without introduction of oxygen and hydrogen gas.

Schei and Schmid, whether taken alone or in combination with any other reference, fail to provide any reason for one of ordinary skill in the art to make or use the presently claimed method. One of ordinary skill in the art, following the disclosures of Schei and Schmid and any other reference would not obtain the presently claimed method.

Mellström does nothing to overcome the deficiencies of Schei and Schmid. Mellström is cited in the Office Action for the disclosure of a method for the purification of silicon in which at least one compound selected from the group consisting of oxides, carbonates, and hydroxides of alkali and/or alkaline earth metals is added to the molten slag. According to the Office Action, it would have been obvious to one of ordinary skill in the art at the time of the invention to substitute powdered sodium carbonate for sodium oxide, as Mellström discloses that sodium carbonate or sodium oxide would result in the same percentage of silicon purification.

At page 1, line 33, to page 2, line 6, Mellström discloses that the method disclosed in that document utilizes a less poisonous melt than prior art methods using a slag comprising CaF_2 , CaO , and SiO_2 , and also uses a considerably lower amount of slag than the prior art slag methods. Therefore, one of ordinary skill in the art, following the disclosure of Mellström would use a slag comprising a solid chlorine compound of an alkali and/or alkaline earth metal

Mellström discloses a method for purifying silicon and a method in which silicon is contacted with a slag, where one of the slag-forming components consists of a solid chlorine

compound of an alkali and/or alkaline earth metal. Mellström also discloses that carbonates and hydroxides of alkali and/or alkaline earth metals as well as silica may be added as slag-forming components. Although, Mellström discloses addition of carbonates of alkali metals as well as silica (SiO_2) as slag-forming components, Mellström requires the addition of a solid chlorine compound.

With regard to the addition of carbonates of alkali metals, at page 2, lines 16 to 20, Mellström discloses that, in addition to the chlorine compound,

Other constituents of the slag which may be present are oxides of alkali and/or alkaline earth metals, and silica. Further constituents that can be used are oxide-forming carbonates and hydroxides of alkali and alkaline earth metals.

Therefore, one of ordinary skill in the art following the disclosure of Mellström would add a solid chlorine compound, silica, and one or more of an oxide of an alkali and/or alkaline earth metal and an oxide-forming carbonate or hydroxide of an alkali and alkaline earth metal. One of ordinary skill in the art modifying the disclosure of the other cited references with the disclosure of Mellström would not add a solid mainly comprising silicon dioxide and a solid mainly comprising one or both of a carbonate of an alkali metal or a hydrate of a carbonate of an alkali metal to molten silicon to form a slag on the molten silicon, as presently claimed.

In addition, the combination of the disclosure of Mellström with that of Schei and Schmid will not provide the presently claimed method. As discussed above, and as cited in the Office Action, Schei discloses the addition of slag, having a lower density than molten silicon, to molten silicon through the bottom or the lower part of a vessel containing molten silicon, such that the slag rises to the top of the molten silicon, and the slag is continuously or substantially continuously removed from the vessel, where $\text{Na}_2\text{O}\cdot\text{SiO}_2$ is disclosed as a slag having a lower density than silicon. If one of ordinary skill in the art substituted the presently claimed powders of Na_2CO_3 and SiO_2 for the $\text{Na}_2\text{O}\cdot\text{SiO}_2$ slag used in the method disclosed by Schei, the resulting method would not purify silicon.

$\text{Na}_2\text{O}\cdot\text{SiO}_2$ may be an example of a slag having a density less than that of molten silicon, as disclosed by Schei, and as stated in the Office Action. However, although Na_2CO_3 powder has a density less than that of molten silicon, SiO_2 powder has a density greater than that of molten silicon. Thus, introducing powders of Na_2CO_3 and SiO_2 into the bottom or lower part of a vessel containing molten silicon, as disclosed by Schei for $\text{Na}_2\text{O}\cdot\text{SiO}_2$, will not form a slag on the top of molten silicon, as presently claimed, as the powders of Na_2CO_3 and

SiO₂ will separate in the molten silicon, one rising to the top and the other sinking to the bottom.

As stated in the Office Action, one of ordinary skill in the art following the disclosure of Schei would introduce any slag forming components, such as the SiO₂ and Na₂CO₃ of the presently claimed method, into the molten silicon in the bottom or lower part of the vessel containing the molten silicon. As is known by those skilled in the art, SiO₂ powder, as generally used in the art, has density of 2.65 g/cm³, and the density of molten silicon is 2.5 to about 2.6 g/cm³. Thus, when SiO₂ powder is added to molten silicon, the SiO₂ sinks.

In contrast to SiO₂ powder, those skilled in the art will know that the density of Na₂CO₃ is 2.5 g/cm³, which is equal to or less than the density of molten silicon. Sodium carbonate, Na₂CO₃, powder also decomposes at the temperature of molten silicon, generating CO₂ and, thus, bubbles, such that the Na₂CO₃ rises through and floats on the molten silicon.

Therefore, should one of ordinary skill in the art introduce Na₂CO₃ and SiO₂ into the bottom or lower part of a vessel containing molten silicon, in the manner disclosed by Schei for the introduction of Na₂O·SiO₂ slag, the Na₂CO₃ would quickly float on the molten silicon, while the SiO₂ would remain on or sink to the bottom of the molten silicon. As a result, if Na₂CO₃ and SiO₂ were introduced into molten silicon in the bottom or lower part of a vessel containing the molten silicon, there would be no contact or reaction between Na₂CO₃ and SiO₂, no slag would form, and the silicon would not be purified. The combination of the disclosures, as suggested by the Office Action, would not provide the presently claimed method.

Applicants submit that Schmid describes that slag is formed from the silica, SiO₂, powder and CaO powder, and that the Office Action states that “introducing silica and CaO in powder form eliminates the step of heating these components separately to form slag before introduction to the molten silicon.” Those comments in the Office Action confirm that SiO₂ powder sinks in molten silicon.

As it is clear that CaO powder, having a density of 3.35 g/cm³ must sink in molten silicon, having a density of about 2.5 g/cm³, it will be understood by those skilled in the art that SiO₂ must also sink in the molten silicon. Otherwise, the CaO and SiO₂ would not react with each other in the molten silicon to form a slag.

That is, if the density of SiO₂ powder was such that SiO₂ powder would float without sinking in the molten silicon, the SiO₂ powder would not react with the CaO in the molten silicon to form the slag. The SiO₂ powder would be on the upper surface of the molten

silicon, and the CaO would be at the bottom of the molten silicon. As the two compounds would not be in contact, there would be no reaction between the CaO and SiO₂ powder.

Thus, based on the teachings of the prior art, one of ordinary skill in the art would expect that when Na₂CO₃ and SiO₂ are provided on the surface of the molten silicon, the Na₂CO₃ and the Na₂O generated by the decomposition of the Na₂CO₃ to form CO₂ float on the molten silicon, while the SiO₂ sinks to the bottom, such that a slag cannot be formed.

However, the presently claimed method provides unexpected results in this regard. Applicants submit that when powders of Na₂CO₃ and SiO₂ are added to molten silicon, bubbles are formed from the CO₂ released by the decomposition of Na₂CO₃ immediately after the addition of the Na₂CO₃. As a result, the SiO₂ powder is entrained in the bubbles of CO₂, and remains floating on the surface of the molten silicon. As the bubbling continues for several minutes, the SiO₂ gradually reacts with the Na₂CO₃ to form the Na₂O·SiO₂ slag. Even after the bubbling due to decomposition of Na₂CO₃ begins to decrease, the remaining Na₂CO₃ and SiO₂ powders continue to float on the molten silicon, and continue to react to form the complete slag over time.

Thus, the presently claimed method provides unexpected results. Prior to the presently claimed invention, those skilled in the art would expect the SiO₂ to sink in the molten silicon. Thus, SiO₂ could react with CaO to form a CaO·SiO₂ slag, as suggested in Schmid, but could not react with Na₂CO₃, as in the presently claimed method. Applicants further submit that there is no prior art disclosure of the addition of Na₂CO₃ and SiO₂ powders to the molten silicon without first converting the powders. *See* the present specification, page 12, lines 20 to 27.

The only method disclosed in the prior art prevent the SiO₂ from sinking when Na₂CO₃ and SiO₂ are added to molten silicon is to add the two compounds in the form of a Na₂O·SiO₂ slag prepared from Na₂CO₃ and SiO₂ prior to the addition.

Schei, which discloses addition of a Na₂O·SiO₂ slag to molten silicon at column 3, lines 27 to 35, also supports the proposition that SiO₂ sinks in molten silicon, as Schei discloses that the Na₂O·SiO₂ slag be formed prior to addition to the molten silicon.

Thus, as discussed above, the presently claimed invention provides unexpected results by forming the Na₂O·SiO₂ slag in the molten silicon from Na₂CO₃ and SiO₂ powders in a manner that prevents the sinking of the SiO₂ in the molten silicon, such that the Na₂CO₃ and SiO₂ coexist on the surface of the molten silicon.

Applicants further submit that the presently claimed method clearly differs from the methods disclosed in the cited references, whether taken alone or in combination, in the

manner in which the boron is removed, i.e., by absorption and distribution of boron in the slag, and the removal of the boron by vaporization.

At page 8, lines 22 to 26, the present specification teaches that the presently claimed invention provides a method for the simultaneous absorption and distribution of boron in the slag, and the removal of the boron by vaporization. In addition, at page 13, lines 23 to the present specification teaches that only when the SiO_2 and a carbonate of an alkali metal, such as Na_2CO_3 , are added to molten silicon is the boron significantly distributed and absorbed in the slag, such that the B boron is vaporized, and removed from the silicon.

The coexistence of the SiO_2 and a carbonate of an alkali metal, e.g., Na_2CO_3 , provides the distribution and absorption of the boron in the slag, enhancing the vaporization of the boron.

In addition, the present specification, at page 13, lines 27 to 37, teaches that charging SiO_2 and a carbonate of an alkali metal, e.g., Na_2CO_3 , into molten silicon using a simple atmospheric melting furnace provides removal of boron from inexpensive metal silicon containing boron to a level of no more than 0.3 mass ppm, and, preferably, no more than 0.1 mass ppm.

The cited reference fail to disclose or suggest enhancement of the absorption and distribution of boron in a slag or the removal of boron by vaporization by making SiO_2 and a carbonate of an alkali metal, e.g., Na_2CO_3 , coexist on the molten silicon.

Although Schmid discloses the introduction of SiO_2 and CaO to form the $\text{CaO}\cdot\text{SiO}_2$ slag, Schmid essentially requires blowing oxygen and hydrogen gases gas into the molten silicon.

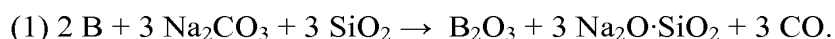
Although Mellström discloses that the carbonate of an alkali metal may be added as a slag component, Mellström requires the addition of a chloride, such as CaCl_2 , as an essential slag forming component.

Therefore, without taking these essential requirements of Schmid and Mellström into account, it is difficult and unobvious to apply only a part of defined requirements of those references, i.e., the addition of SiO_2 or Na_2CO_3 powder, to Schei unless the actions and effects of the modifications required by the Office Action are clear. It is well settled law that each reference must be taken as a whole.

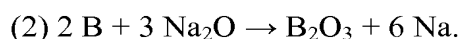
Applicants submit that that the present specification, at page 5, lines 27 to 35, teaches that the method disclosed in Schmid requires blowing oxygen and hydrogen gas through a specific torch, and that, at page 8, lines 7 to 11, the present specification teaches that the present invention provides a method that avoids the need for gas blowing.

Applicants also submit that, at page 6, lines 21 to 25, the present specification teaches that the method disclosed by Mellström requires adding a chloride, e.g., CaCl_2 , and, at page 8, lines 11 to 15, also teaches that the present invention provides a method that allows the addition of a chloride to be avoided.

Applicants further submit that the presently claimed method unexpectedly facilitates the removal of boron from molten silicon. In order for boron B to be absorbed into the slag, and removed from the molten silicon, it is necessary to first oxidize the boron to form the boron oxide B_2O_3 . In the present invention, as since Na_2CO_3 and SiO_2 coexist, the oxidation of B proceeds in accordance with the reaction (1).



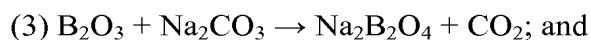
Therefore, if Na_2CO_3 and SiO_2 do not coexist, and the boron is oxidized by Na_2O , the reaction (2) occurs.



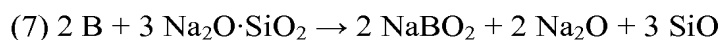
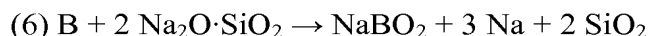
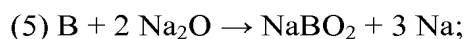
Reaction (2) generates simple atomic Na, and requires large amounts of energy, such that reaction (2) hardly proceeds.

The presently claimed method also provides the accelerated vaporization of boron.

At page 15, lines 24 to 31, the present specification teaches that the removal of boron by vaporization facilitates the purification of the molten silicon. With the presently claimed method, boron is vaporized in the form of NaBO_2 . The B_2O_3 generated in reaction (1) further reacts with Na_2CO_3 in accordance with the reactions (3) and (4).



When Na_2CO_3 is not present, reaction (1) does not proceed, but Na_2O or a $\text{Na}_2\text{O} \cdot \text{SiO}_2$ slag is present, vaporizable NaBO_2 can only be generated by one of the following reactions (5) to (7).



However, with reactions (5) to (7), Na or SiO is generated. In addition those reactions require large amounts of energy. Therefore, those reactions proceed very slowly.

As discussed above, to vaporize boron, reactions (1) and (3) must occur. Therefore, both Na_2CO_3 and SiO_2 must coexist with the molten silicon. Even if Na_2O or a $\text{Na}_2\text{O} \cdot \text{SiO}_2$ slag is present, the vaporization of boron will not occur. It is only through the presently claimed method that this vaporization of boron occurs.

Therefore, Schei, Schmid, and Mellström, whether taken alone or in combination, fail to provide any reason for one of ordinary skill in the art to make or use the presently claimed method, and, thus, the present claims are not obvious over those references. Accordingly, it is respectfully requested that the Examiner withdraw the rejection of claims 1 to 15 under 35 U.S.C. § 103(a) over Schei, Schmid, and Mellström.

Hurley does nothing to overcome the deficiencies of Schei, Schmid, and Mellström. Hurley is cited in the Office Action for the disclosure of the addition of alumina to a slag composition to increase the viscosity of the slag, making the slag less corrosive.

However, even if the disclosure of Hurley was combined by one of ordinary skill in the art with the disclosures of Schei, Schmid, and Mellström, the resulting combination would not provide the presently claimed method. One of ordinary skill in the art following the disclosures of Schei, Schmid, Mellström, and Hurley would have no reason to make or use the presently claimed method.

Therefore, as Schei, Schmid, Mellström, and Hurley, whether taken alone or in combination, fail to provide any reason for one of ordinary skill in the art to make or use the presently claimed method, the present claims are not obvious over those references. Accordingly, it is respectfully requested that the Examiner withdraw the rejection of claim 16 under 35 U.S.C. § 103(a) over Schei, Schmid, Mellström, and Hurley.

Applicants thus submit that the entire application is now in condition for allowance, an early notice of which would be appreciated. Should the Examiner not agree with Applicants' position, a personal or telephonic interview is respectfully requested to discuss any remaining issues prior to the issuance of a further Office Action, and to expedite the allowance of the application.

A separate Petition for Extension of Time is submitted herewith. Should any other fees be due, however, please charge such fees to Deposit Account No. 11-0600.

Respectfully submitted,

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